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Generation and recombination in semimetallic heterostructures

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Heterojunctions InAs-GaSb belong to the most interesting objects in the modern semiconductor physics [1]. Due to the partial overlapping of the InAs conduction band with the GaSb valence band, a semimetallic electron-hole system is formed at the interface. Contrary to ordinary semimetals (Bi), electron and hole systems in these heterostructures are spatially separated. That is why the current flow through single heterojunctions and multilayer heterostructures is governed by generation-recombination processes at the InAs-GaSb interface.

The aim of the present work is to calculate the interface generation-recombination (GR) rate. We considered the three-band Kane model Hamiltonaian [2] within the envelope-function approximation to calculate GR rate. We found that the generation-recombination processes in semimetallic heterojunctions are very different compared to those in ordinary semiconductors, p-n-junctions and other heterojunctions. In particular, the creation of electron-hole pairs requires no additional energy and, hence, the generation rate must have no activation temperature dependence. An electron of InAs reaching the interface can either reflect back or with some probability transmit into the valence band of GaSb. Such a transition is equivalent to a recombination of elelctron-hole pair. The process when electrons from the valence band of GaSb penetrate into InAs, is equivalent to the generation of an electron-hole pair at the interface. So, generation-recombination at the interface does not require the presence of any third body (photon, phonon, recombination center, etc.).

We applied the present theory to describe the conduction processes in heterojunctions n-InAs–p-GaSb. We found that the current-voltage characteristics of the junction n-InAs–p-GaSb have the properties of an Ohmic contact, in agreement with the experimental results [3]. As the applied voltage U increases, the current-voltage characteristics become non-linear and finally saturate for $eU > \Delta$ at the value independent of the temperature. The results obtained above can also be applied to the InAs–GaSb superlattices. If the thickness of superlattice layers is of order of 100 Å or more, the superlattice is in a semimetallic state and contains alternating layers with high electron and hole concentration. It is usually assumed that the superlattice conductivity is provided by formation of electron and hole minibands. However, at large superlattice periods miniband conductivity will be very small. In this case we may expect that the conductivity in InAs layers will be provided by electrons, in GaSb – by holes and the total superlattice conductivity will be governed by generation-recombination processes at the interfaces. As a result the superlattice conductivity per unit area will be inversely proportional to the number of layers.

References

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[2] P. Voisin, refeence 1, p. 85.
[3] H. Sakaki, et al. *Appl. Phys. Lett.* **31**, 211 (1977).